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William J. Hutzell  
*Purdue University*, [hutzellw@purdue.edu](mailto:hutzellw@purdue.edu)

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# AN INTERDISCIPLINARY SOLAR ENERGY PROJECT

William J. Hutzel

Department of Mechanical Engineering Technology  
Purdue University

## Abstract

*An HVAC course, previously offered to students in Mechanical Engineering Technology (MET), has been re-structured to include students in Building Construction Management (BCM). A large project is always an integral part of this course, creating a unique opportunity for collaboration between two distinctly different groups of Technology students. This cooperation is particularly beneficial because MET and BCM graduates frequently cross paths during their professional careers. Many MET graduates operate and service heating, ventilating, and air conditioning equipment that was originally specified and installed by BCM graduates. This paper discusses and evaluates student interactions during a solar energy renovation project that was completed in the Spring of 1996.*

## Interdisciplinary HVAC Course

The rapid construction of new commercial buildings, which has been vigorous since the 1980's, has created two outstanding technical career opportunities. Qualified mechanical contractors who specify and install plumbing, electrical, and climate control equipment are in short supply. The opportunities for facility managers, who use sophisticated building automation systems to operate and maintain the mechanical equipment on a daily basis, have never been better. In fact, facilities management is projected to be one of the fastest growing technical careers over the next 10 years.

Two departments within the School of Technology at Purdue University, Building Construction Management (BCM) and Mechanical Engineering Technology (MET), are developing interdisciplinary courses that specifically address these areas of growth. This approach gives two distinctly different groups of students who share an interest in commercial buildings the opportunity to work and learn from each other. The cooperation is particularly beneficial because mechanical contractors (former BCM students) and facility managers (former MET students) frequently collaborate during new construction and building renovation projects.

As a starting point for the collaboration, BCM students are enrolling in a new version of the MET Heating, Ventilating, and Air Conditioning (HVAC) course. In the past, when two thermodynamic courses were prerequisites, energy-based analyses of HVAC equipment were the primary course topics. As much as 1/2 of each semester was devoted to various refrigeration cycles. The revised course, intended for mechanical contractors and facility managers, has a different focus. More modest prerequisites, such as general physics and integral calculus, encourage BCM students to participate. The new topics include a review of basic thermodynamics including refrigeration, psychrometrics, heating/cooling load estimation, and duct design. The course is structured around two 1-hour lectures and one 2-hour laboratory experiment each week.

## Team Oriented Projects

Laboratory work has always been an important component of the HVAC course. Actual Pressure and temperature measurements on a real refrigeration system certainly illustrate cooling principles more clearly than a lecture. Although it is not usually emphasized, laboratory experiments also teach important lessons about team work. Most of the HVAC experiments were designed so that students work in groups during data collection and analysis. Work is completed more quickly, and frequently more correctly, if tasks are delegated among a small group of students.

Although laboratory experiments are very informative, they also have inherent limitations. The explicit step-by-step instructions that accompany most experiments in the HVAC course unintentionally teach students to expect clear cut solutions. Students quickly become adept at "plug and chug" calculations. Unfortunately, this type of work does not reflect the complexities of many industrial problems. Based on my experiences outside of academia, many technology or engineering graduates are extremely good at generating numbers and equations but have trouble evaluating the feasibility of their answers.

Semester projects are an important alternative to standard laboratory experiments in the HVAC course. Once each semester students work in project teams to solve a "real world" problem. Each project is four to five weeks in duration as opposed to one week for a typical laboratory experiment. A past project includes sizing heating equipment for an industrial facility. The project had a significant real world component because in addition to basic energy calculations, students also considered first cost, equipment features, and delivery schedule. Common sense and engineering judgment were required to select the best equipment from among several alternatives.

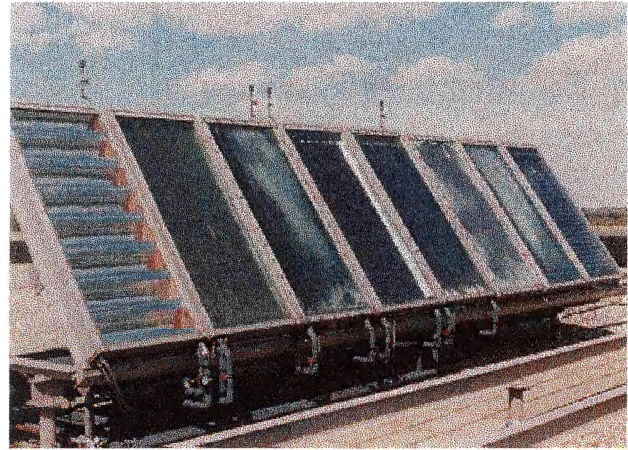
The new interdisciplinary HVAC course offers fresh and exciting incentives for semester projects. BCM and MET students have different perspectives on building operation and maintenance. While BCM students are accustomed to scheduling and cost estimating, MET students are more comfortable specifying mechanical equipment. The new HVAC course fosters interaction between students who may cooperate during their professional careers and is a closer match to an actual work environment.

### Solar Energy Project

The solar energy system, located in Applied Energy Laboratory of the Knoy Hall of Technology, demonstrates renewable energy sources to thermodynamics students. Figure 1 shows eight different solar collectors located on the roof above the laboratory. The five collectors to the left use propylene glycol as the active fluid, while the three to the right use forced air. Each collector is slightly different, some have fins on the absorber surface and others have a flat black background. Students calculate and compare energy conversion efficiency (energy collected/energy available) of the different collectors for one of the HVAC laboratory experiments.

Although the principal components of the solar energy system were operational, there was a growing number of problems with day to day operation. By the Spring of 1996, the system had been in continuous operation for more than 10 years. The energy conversion efficiency was about 1/2 of what could reasonably be expected for a solar energy apparatus located in West Lafayette, Indiana. Problems with the propylene glycol loop were particularly apparent. An excessive number of air bubbles and lack of flow was visible through a sight glass. On sunny days the

propylene glycol temperature approached the point where thermal breakdown could occur.



*Figure 1. Solar collectors demonstrate alternative energy sources.*

Despite repeated attempts, "trial and error" remediation had been unsuccessful at alleviating the problems with the propylene glycol loop. Numerous air traps did not eliminate the air bubbles. Likewise, a new pump did not increase flow. After spending several hundred dollars on the system with few positive results, it was clearly a bad decision to spend more money unless a full investigation was made.

A comprehensive evaluation of the malfunctioning solar energy system was an ideal interdisciplinary project. The open ended nature of the investigation was a striking contrast to the prescriptive laboratory experiments that were completed earlier in the semester. Students had to apply their technical knowledge to a unique situation whose outcome was not known in advance. It also required broad range of expertise. Both thermodynamics and fluid dynamics, two core topics for an MET student, were required to analyze the piping network and assess energy efficiency. On the other hand, significant project management and project coordination was familiar ground for BCM students.

### Project Implementation

The solar energy project was introduced early in the semester even though most of the work was completed much later. The project goals were introduced on the first day of class so that students could begin to form interdisciplinary teams. Each team signed up for one of the six tasks identified in Table 1. With 22 students in the class there were about 4



students on each team. Unfortunately, the 20 Mechanical Engineering Technology Students easily outnumbered the 2 Building Construction Management students. Since the HVAC course has now become a requirement for BCM students in a popular Mechanical Contracting Option, a more even distribution of MET and BCM students is expected in the future.

*Table 1. Students joined one of six project teams.*

Team Number	Task Description
1	Heat Exchanger Analysis
2	Glycol Loop Evaluation
3	Air Loop Evaluation
4	Solar Collector Inspection
5	Laboratory Integration
6	Project Management

As reflected in Table 1, each team focused on one part of the solar energy system. For example, Team Number 1 identified a plate and frame heat exchanger capable of removing solar energy from the propylene glycol loop. One specific technical task was estimating the magnitude of the peak solar load and one of the project management tasks was interacting with heat exchanger manufacturers to select an optimum unit. Their results were documented in one chapter of the final technical report and discussed during a final technical presentation.

Two student project managers (Team Number 6 in Table 1) linked the student teams with the instructor. Early in the semester the student project managers developed a detailed work schedule. Once the project began, student project managers coordinated day to day efforts. The students working on the glycol loop (Team Number 2) needed pressure drop data from the heat exchanger group (Team Number 1). In turn, the heat exchanger group needed guidance from the instructor. The project managers made sure that all information was available and on time. Even though student project managers did not complete any technical tasks they were ultimately responsible for the success of the project.

Since few students had previous experience with solar energy, early classroom discussions were used to introduce the topic. Rather than a detailed technical overview, the discussions centered on the more general issue of how to find information about any new technical topic. Many students, accustomed to working inside the constraints of a laboratory manual, were unsure where to look. After describing technical

journals and pointing out some of the new capability of the internet, a research paper on solar collectors was assigned. The dialog on solar collectors continued throughout the semester. Particularly after the project started, significant lecture time was allocated for discussing potential trouble spots and the project schedule.

## Results

The project teams were successful with most aspects of the project and made a lasting contribution to the Applied Energy Laboratory. Team Number 2 corrected problems that had been plaguing the glycol loop for many months. After studying the components, students recognized that the propylene glycol loop was not completely full. A larger charging pump was needed to completely fill the system. Once the loop was full of propylene glycol many of the problems that had plagued the system (excessive air bubbles, lack of flow, and high cycle temperatures) were eliminated. Team Number 2 got first hand experience in troubleshooting a mechanical system. More specifically, they learned about the interaction between a pump and a piping network.

Success was more dependent on each team's initiative than on any particular technical background. Students in either Building Construction Management or Mechanical Engineering Technology who made a significant effort were equally successful. At one extreme, the team responsible for evaluating the heat exchanger had very little trouble. They worked without assistance and aggressively sought out information. At the opposite extreme, the team responsible for inspecting the solar collectors had difficulty with most aspects of their task. They found it much easier to identify problems than to find solutions. Most of their work was completed at the last minute. The group had plenty of technical ability, but lacked initiative.

## Student Feedback and Conclusions

Despite the successful results, student reaction toward the solar energy project was mixed. It is not surprising that many students preferred structured laboratory experiments. One student noted that "the project should be more directed, we cannot specify things we know little about". On the other hand, some students recognized the benefits of an open ended project. One student stated that "The solar energy project was a good part of the course. It helped both

students and faculty by educating and producing useful information".

A comprehensive investigation of a solar energy system was an ideal project for an interdisciplinary HVAC course. However, many of the most important lessons were not about solar energy. The project demonstrated the role of engineering judgment and team work on real world projects. These lessons should be a useful for students pursuing careers as mechanical contractors or facility managers. The project also provided a long term benefit to the Applied Energy Laboratory. The final report on the solar collectors, developed entirely by students, will guide plans for operating and maintaining the system in the future.

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### **References**

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